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1509-483

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: Ian Peter CRIGHTON et al.   Conf.:   2965

Serial No.: 10/767,864   Art Unit: 2652

Filed: January 30, 2004   Examiner: Not assigned

For: DIGITAL DATA STORAGE UNITS

SUBMISSION OF PRIORITY DOCUMENT

Commissioner for Patents   **September 24, 2004**
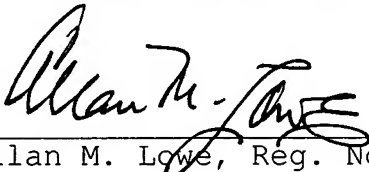P. O. Box 1450
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Sir:

At the time the present application was filed, priority was claimed based on British Application No. 0302246.4, filed January 31, 2003. A copy of the priority document is attached.

Respectfully submitted,
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Dated　31 March 2003

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1.	Your reference	200206115-1 GB

2.	Patent application number *(The Patent Office will fill in this part)*	**0302246.4** 31 JAN 2003

3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Hewlett-Packard Company 3000 Hanover Street Palo Alto CA 94304, USA 496 588001
	Patents ADP number *(if you know it)*	
	If the applicant is a corporate body, give the country/state of its incorporation	Delaware, USA

4.	Title of the invention	Improvements Relating to Digital Data Storage Units

5.	Name of your agent *(if you have one)*	Denise Kilgannon Hewlett-Packard Ltd, IP Section Filton Road, Stoke Gifford Bristol BS34 8QZ
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	
		7563083001
	Patents ADP number *(if you know it)*	

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

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8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* a) *any applicant named in part 3 is not an inventor, or* b) *there is an inventor who is not named as an applicant, or* c) *any named applicant is a corporate body.* *See note (d))*	Yes

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Description 21

Claim(s) 7

Abstract 1

Drawing(s) 7 *only*)

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11.   I/We request the grant of a patent on the basis of this application.

Signature *Denise Kilgannon*   Date 31.1.03

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12. Name and daytime telephone number of
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- 1 -

5 IMPROVEMENTS RELATING TO DIGITAL DATA STORAGE UNITS

FIELD OF THE INVENTION

The invention relates to digital data storage units, more particularly but not

exclusively tape data storage cartridges, and to a method and data transfer

10 device for use with such data storage units.

BACKGROUND

Occasionally, an unusually and unacceptably high error rate occurs during

the transfer of data between a data transfer device and a data storage unit

15 removably inserted in the data transfer device. It is desirable to establish

whether a cause of the fault lies in the transfer device or the storage unit, so

that remedial action can be taken. However, it is generally not immediately

evident whether the error is due to a fault in the transfer device or the storage

unit, and establishing the location of the cause of the fault can be potentially

20 time consuming and frustrating.

SUMMARY OF THE INVENTON

In accordance with one aspect of the invention, there is provided a method

for use in an automated storage apparatus for moving digital data storage

5   units relative to at least one digital data transfer device, the method

comprising:

a) recognizing a designated one of said digital data storage units as a

reference unit for diagnostic use, said unit comprising at least one

storage portion; and

10   b) using a record of data transfer operation occurrences performed

relative to the or each storage portion so as to limit a number of

data transfer operations performed on the or each storage portion.

In accordance with a further aspect of the invention, there is provided a

15   digital data transfer device for transferring data to and from digital data

storage units, said device being adapted to:

a) recognize a said digital data storage unit as a reference unit for

diagnostic use, said reference unit comprising at least one storage

portion;

20   b) access a record of data transfer operations performed relative to the

or each said storage portion of said reference unit; and

c) use said record to limit a number of data transfer operations

performed on each said storage portion.

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5 In accordance with a still further aspect of the invention, there is provided a

digital data storage reference unit comprising i) at least one reference data

storage portion and ii) a record of a number of times a data transfer

operation has been performed relative to the or each said storage portion, so

as to enable maintenance of the or each said data storage portion in a

10 predetermined reference condition.

In accordance with a still further aspect of the invention, there is provided a

method of operating an automated storage apparatus comprising at least one

data transfer device for transferring data to and from data storage units, a

15 robotic device for moving said data storage units, a holding area for holding

said data storage units for which no data is presently required to be

transferred thereto or therefrom, and a reference data storage unit held in

said holding area, the method comprising: automatically, in response to

receiving information indicative of an excessive error level in transferring

20 data between one said data transfer device and a respective said data storage

unit:

a) removing from said one data transfer device a presently inserted

said data storage unit; and

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5   b) inserting said reference unit in said one data transfer device for a

reference transfer operation.

In accordance with a still further aspect of the invention, there is provided an

automated digital data storage apparatus for moving digital data storage

10   units between a holding area and at least one respective data transfer device

for transferring data to and from said data storage units, said apparatus being

adapted to:

    · a) hold and locate in said holding area a said data storage unit that is

designated as a reference unit for diagnostic use, said unit

15   comprising at least one reference storage portion having had a

controlled number of previous transfer operations performed

thereon; and

    b) automatically, in response to receiving information indicative of an

excessive error level in transferring data between one said data

20   transfer device and a respective said data storage unit:

        i)   remove from said one data transfer device a presently

inserted said data storage unit;

        ii)   insert said reference unit in said one data transfer device

for a reference transfer operation.

- 5 -

In accordance with a still further aspect of the invention, there is provided an automated digital data storage apparatus for moving digital data storage units between a holding area and at least one respective data transfer device for transferring data to and from said data storage units, said holding area having a slot dedicated to receiving one of said storage units that is designated as a reference unit for diagnostic use, said reference unit comprising at least one reference storage portion having had a controlled number of previous transfer operations performed thereon, said apparatus being adapted to:

    a) monitor an error-level in data transferred between the or each said data transfer device and a respective said data storage unit;

    b) automatically, in response to a said error level at one said transfer device exceeding a predetermined threshold:

        i)   remove from said one data transfer device a presently inserted said data storage unit; and

        ii)   insert in said one data transfer device said reference unit.

BRIEF DESCRIPTION OF THE DRAWINGS

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5　　In order that the invention may be well understood, by way of example only,

　　various embodiments thereof will now be described with reference to the

　　accompanying drawings, in which:

　　Figure 1 is a schematic representation of an automated digital data storage

10　apparatus;

　　Figure 2 shows a digital data storage unit including a tape data storage

　　medium and a fast access storage device;

15　Figure 3 is a schematic representation of a tape data storage medium of the

　　unit of Figure 2;

　　Figure 4 shows a table of data stored on the storage unit;

20　Figure 5 is a schematic representation of an alternative tape data storage

　　medium;

　　Figure 6 is a diagram illustrating a method of operating an automated

　　storage apparatus;

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5

Figure 7 illustrates a method for use in an automated storage apparatus; and

Figure 8 is a schematic representation of an alternative automated digital data storage apparatus.

10

DETAILED DESCRIPTION

Figure 1 shows an automated data storage apparatus in the form of a tape library 1 having a plurality of data transfer devices in the form of tape drives 3 and a holding area 5 having a plurality of holding bays 7 comprising

15   shelves or other tape-library compartments. The drives 3 removably receive respective digital data storage units in the form of tape cartridges 9, for performing read and write operations to transfer data to and from the received cartridges 9. The holding bays 7 removably receive respective tape cartridges 9 for storing cartridges 9 that are not presently required for data

20   transfer purposes.

The library 1 also has a robotic accessor apparatus 11 for moving the cartridges 9 between various physical locations in the holding area 5 and the data transfer devices 3, and inserting and/or removing the cartridges 9 at

- 8 -

5　those locations as required. The accessor apparatus can be implemented by,

for example, robotic arms, integrated loading equipment, conveyors,

grippers movable on an x-y system, or any other suitable cartridge

movement apparatus. The library 1 also allows cartridges to be input to or

output from the library by some convenient means (not shown).

10

The library 1 is controlled by a library controller 13, for controlling the

movement of cartridges between locations or addresses in the library 1. The

controller 13 is conveniently connected to a man machine interface 16. The

controller 13 receives movement control commands from a media server

15　host 12, comprising at least one digital machine, through an input and/or

output path 14. The host 12 is adapted to receive movement control requests

along a communications path 29 and send out movement reporting signals

along the path 29. The controller 13 is adapted, in response to receiving

movement control commands from the host 12, to issue control signals to the

20　accessor apparatus 11 to cause the accessor apparatus 11 to access cartridges

9 from selected physical locations or addresses (drives 3 or holding bays 7)

in the library 1 and to move the cartridges 9 to other selected physical

locations 3, 7 or addresses. The movement control requests received by the

host 11 can relate to movement of cartridges 9 between logical (i.e. virtual)

- 9 -

5   addresses, in which case the host 11 is adapted to translate the logical

address to a physical addresses before instructing the controller 13.

In the embodiment of Figure 1, the controller 13 comprises digital data

processing apparatus including a digital data processor 15, fast access

10   storage 17, for example random access memory (RAM), and non-volatile

storage 19, for example electrically erasable progammable read only

memory (EEPROM) or other suitable device. A program (not shown) is

stored in the non-volatile storage 19, the program comprising sequences of

machine readable instructions executable by the processor 15 to cause the

15   library 1 to perform as described below.

An exemplary one of the cartridges 9 is shown in Figure 2. The cartridge 9

comprises a casing 25 and, internally of the casing 25, one or a pair of reels

(not shown) on which is wound an elongate band of magnetic tape 27

20   (Figure 3) constituting a high capacity data storage medium. When inserted

in one of the tape drives 3, the magnetic tape 3 can be driven on the reel or

reels to enable transfer of data to and/or from the tape as it passes magnetic

read and/or write heads of the drive 3. The cartridge 9 and drives 3 of the

present embodiment relate to linear tape technology, such as the LTO 2

5   standard for example, wherein a write and/or read pass is generally made in

a direction of a longitudinal axis of the tape 27 and then continues if

required in an opposite direction. However, alternative embodiments relate

to other technologies, for example helical scan technology such as the DDS

4 standard, wherein a write and/or read pass is made in a direction laterally

10   of the tape 27 at an angle to the longitudinal axis of the tape 27.

The cartridge 9 includes a fast access data storage device 29 in the form of a

solid state programmable memory device. The memory device 29 can

require contact with another device, for example a tape drive 3, for

15   communicating with the other device, or can alternatively be contactless.

For example, the memory device 29 of in Figure 2 is contactless and

includes a transponder unit (not shown) and a non-volatile read/write

memory that can be written to or read via the transponder unit. The

transponder unit can be inductively powered by an RF signal generated by a

20   transmitter, for example in a tape drive 3, when placed immediately adjacent

the cartridge casing 25, as is known in the art. The dimensions and layout of

the casing 100, including the position of the memory device 29, are specified

for any particular type of cartridge 9. Information about the cartridge 9 and

any data stored on the tape 27 can be stored in the memory device 29, for

- 11 -

5   example locations of certain data blocks and storage dates, customer

information, details of an application stored on the tape, remaining unused

tape storage space.

The drives 3 are connected over data input/output lines 31 to data sources

10   32. The data sources 32 may be connected to the library's drives 3 in any

convenient arrangement. For example, the data sources 32 can be directly

connected to respective drives 3 for supplying data streams to the drives 3 on

a one-to-one basis, with multiple drives 3 to one data source 32, or in any

other suitable manner. Alternatively, the data sources 32 can be connected

15   to the drives 3 through a switched fabric arrangement (not shown) or

through the host 12.

In use, the host 12 receives a cartridge movement control request from an

originating data source 32 and sends a corresponding movement control

20   command to the library controller 13, translating logical addresses to

physical addresses where necessary. If the required cartridge is not

successfully located, the controller 13 may send information to the host 12

alerting it to the need to provide the required cartridge to the library 1. If a

required cartridge is not in a presently available drive 3, the controller 13

- 12 -

5   selects a drive and instructs the robotics 11 to move the required cartridge 9

to a selected drive 3. In response to the robotics confirming that the cartridge

9 is correctly positioned, the host 12 sends a movement reporting signal to

the originating data source 32 over the line 29. In response to receiving the

confirmatory reporting signal from the host 12, the data source 32 initiates

10   data streaming to the drive 3.

Coordination of data streaming to the drives with cartridge movement can be

carried out using any convenient and suitable arrangement, many of which

which be apparent to the skilled reader. For example, the data sources 32

15   and host 12 may be interconnected over a LAN forming part of a storage

area network (SAN), or by any other suitable arrangement, and at least one

of the data sources 32, the host 12, some other networked device or a

combination of any of these devices can control coordination of storage

traffic commands.

20

Each drive 3 operates under control of it own internal logic circuitry (not

shown), or a processor (not shown) executing machine readable instructions

adapted to cause the drive to operate as described below. The drive 3

monitors an error level in data transferred to or from a cartridge 9, the so-

5   called "soft" error rate, i.e. the error rate prior to the application by the drive

3 of error correction techniques. If the error level exceeds a predetermined

threshold, the drive 3 operates to inform the controller 13 of the excessive

error level at the drive 3 (Figure 6, step 61). In response to receiving the

information indicative of an excessive error level from a particular drive 3

10   (Figure 6, step 63), the library controller 13 enters an auto-diagnostic mode.

In this mode, the controller 13 makes the drive 3 temporarily unavailable to

the host 12 for further data transfer operations, and removes the presently

inserted cartridge 9 from the drive 3 (Figure 6, step 65). The controller 13

also records details of the error level at the drive 3, if required. The

15   controller 13 causes the robotics to temporarily store the potentially faulty

cartridge 9 in a location in the holding area 5, and makes a record containing

details of the location and the cartridge 9.

The controller 13 operates to cause the robotics 11 to locate a designated

20   reference cartridge 9R constituted by a cartridge 9 that has been designated

as a reference cartridge for diagnostic use as described below. A specially

designated storage slot 35 is provided in the holding area 5 for holding the

reference cartridge 9R. The slot is hidden in that it is not available to the

library 1 for use in holding a cartridge 9 storing user data. The reference

- 14 -

5   cartridge 9R has identity information stored in a designated field in the

cartridge memory device 29, enabling the controller 13 and/or drives 3 to

use the information to recognize the reference cartridge 9R as containing a

known storage medium for diagnostic use. The reference cartridge 9R can

be specially marked or configured for easy human recognition.

10

In alternative embodiments, the identifying information could be provided in

other ways, for example by storage on the magnetic tape 27 or by a

mechanical cartridge recognition system. Alternatively, the identifying

information could be dispensed with, and the reference cartridge 29 could be

15   located initially by virtue of its position in the special slot 35 and then

tracked by the library controller 13 as it moves in the library 1. Also, it will

be understood that in certain embodiments the special slot 35 could be

dispensed with and the controller 13 could store the reference cartridge 9R

in any convenient one of the holding bays 7, using the identity information

20   to locate the reference cartridge when required.

The reference cartridge 9R has a designated field in its cartridge memory

device 29 for recording a history of read and/or write operations performed

on at least one storage portion 28 of the magnetic tape 27. The tape 27

- 15 -

5   shown in Figure 3 is approximately 600 metres long and is notionally

divided into ten storage portion 28s each about 60 metres long. However, it

will be appreciated that any convenient alternative size, number and

arrangement of storage portions 28 could be selected. For example, the

storage portions 28 need not be contiguous as shown, and could be

10   distributed across the tape 27. The most appropriate arrangement will

depend on the particular storage technology employed. The history can be

recorded in any convenient form, for example in a table 37 as shown in

Figure 4, that records the number of times each storage portion 28 has been

used in a read and/or write operation.

15

The library controller 13 causes the robotics 11 to move the reference

cartridge 9R to the drive 3 experiencing the excessive error level and insert

the cartridge 9R into the drive 3 (Figure 6, step 67). The drive 3 operates to

communicate with the cartridge memory device 29 of the reference unit 9R.

20   The drive 3 accesses the identity information and recognizes the drive as a

reference unit (Figure 7, step 81). The drive then accesses the history table

37 (Figure 7, step 83). In an alternative embodiment, at least one of the

identity information and the history table 37 are stored on a specially

reserved portion of the magnetic tape 27, and the drive 3 operates to access

- 16 -

5   the specially reserved portion of the tape 27 to obtain the necessary

information.

The drive 3 is adapted to use the occurrence record provided by the history

table 37 to enable it to carry out a reference read and/or write operation only

10   on a storage portions 28 that has not previously been subject to a read and/or

write operation (Figure 7, step 85). In this manner, only virgin tape is

presented to the drive's read and/or write heads for the reference read and/or

write operation. The virgin tape storage portions should be in good

condition, and will not have been subject to damage caused by wear and tear

15   occasioned by previous data transfer operations, for example scratches

caused by dirt or debris on the read/write heads, or overuse.. In alternative

embodiments, the drive 3 could operate to allow two, or some other

relatively low number of data transfer operations, per storage portion 28.

After carrying out a reference data transfer operation on the selected storage

20   portion 28, the drive operates to update the history table 37 by incrementing

the table 37 against the entry for that storage portion 28 (Figure 7, step 87).

The drive 3 monitors the error level in data transferred between the drive 3

and the reference cartridge 9R (Figure 6, step 69). If the error level exceeds

- 17 -

5   a predetermined threshold, the drive 3 operates as previously, to inform the

controller 13 of the excessive error level at the drive 3. Alternatively, the

controller 13 carries out a diagnostic operation using information obtained

from the drive during the reference data transfer operation to determine

whether the error level exceeds the predetermined threshold. The controller

10   13 automatically takes appropriate action depending on the error level of the

reference data transfer operation.

An excessive error level using the reference cartridge is indicative of a fault

in the drive 3, and accordingly the controller 13 takes action to, for example,

15   provide a warning signal or message to alert a library operator that there is a

fault in the drive and/or to take the drive offline and make the host aware

that the drive 3 is no longer available (Figure 6, step 71). If the reference

error level is not excessive, the controller 13 takes action to, for example,

provide a warning signal or message to alert the library operator that the last-

20   removed cartridge 9 is faulty or degraded, and/or provide the location of the

removed cartridge 9 in the holding area 5 and/or make the faulty cartridge 9

inaccessible for further move operations except for export from the library 1

(Figure 6, step 73).

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5   In this manner, a library operator can be informed of a fault in a specific

drive 3 or cartridge 9, and/or appropriate action can be taken to mitigate the

effects of the fault, without any prior involvement of the operator. This

saves the operator's time and removes a need for the operator to be involved

in low level data analysis.

10

An alternative reference cartridge 9R is identical to the cartridge 9R

described above except that the magnetic tape 27 is replaced by a multi-

function band 40, shown in Figure 5. The band 40 has a portion of magnetic

tape 27 connected at one end to an end of a tape cleaning band 37 of

15   abrasive tape cleaning material. The tape 27 and the band 40 are connected

by a spliced joint 41. The alternative cartridge 9R carries identity

information identifying it as a multi-function cartridge.

The multi-function cartridge can be used in a method as described above,

20   except that the library 1 and drives 3 are adapted to recognize the multi-

function cartridge 9R and use it as a cleaning cartridge or as a reference

cartridge as required. Only one special slot 35 need be provided to hold the

multi-function cartridge 9R.

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5   The term "library" as used herein includes autoloader devices, for example a

multi-cartridge autoloader device 1A as shown in Figure 8 comprising only

one drive 3. In such an autoloader device 1A, for example using "surrogate

SCSI" technology, cartridge movement control commands and a data stream

can be sent over the same communication path 31. The drive 3 fulfils the

10   functions of the host 12 and passes-through cartridge movement control

commands to the library controller 13.

Whilst the cartridge 9 and drives 3 of the present embodiment relate to linear

tape technology, alternative embodiments relate to other tape technologies,

15   for example helical scan technology such as the DDS 4 standard, wherein a

write and/or read pass is made in a direction laterally of the tape 27 at an

angle to the longitudinal axis of the tape 27. It will also be understood that

the invention can be analogously implemented using any other suitable data

storage technology, for example using optical or magnetic disc data storage

20   units and transfer devices.

Furthermore, it will be appreciated that the controller 13 can be implemented

in many alternative forms. For example, at least one of the fast access

storage 17 and non-volatile storage 19 could be dispensed with or located

- 20 -

5   externally of the controller 13, or the necessary storage could instead be formed integrally with the processor 15. Alternatively, the digital data processing apparatus 13 could be replaced by logic circuitry adapted to cause the library 1 to perform a method as described above. The logic circuitry could be, for example an application specific integrated circuit

10   (ASIC), digital signal processing (DSP) chip, discrete circuit components, programmable logic array, or any other suitable circuitry.

The program executable by the processor 15 to cause the library 1 to perform the method described above can be stored on any suitable

15   alternative carrier instead of the fast-access storage 17 carrier and the non-volatile storage 19 carrier. An alternative carrier could be formed by, for example, a magnetic disc drive (e.g. hard drive and RAID), solid state memory (e.g. ROM, EPROM, EEPROM), magnetic disc, optical disc (e.g. CD-ROM, DVD), magnetic or optical tape, wired or wireless transmission

20   media, a digital data processor, or any other suitable signal-bearing medium.

Alternatively, at least part of the program could be executed by the host 12 and the controller 13 could receive commands from the host 12 to cause the controller 13 to perform the method described above.

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5

At least some of the functions for performing steps of described above that

are implemented by the controller 13, drives 3 or host 12 using logic circuits

or machine readable instructions could equally well be implemented by

another of these devices, or distributed between two or more of those

10   devices, without departing from the scope of the invention claimed.

5   CLAIMS

1. A method for use in an automated storage apparatus for moving digital

   data storage units relative to at least one digital data transfer device, the

   method comprising:

10   a) recognizing a designated one of said digital data storage units as a

                  reference unit for diagnostic use, said unit comprising at least one

                  storage portion; and

            b) using a record of data transfer operation occurrences performed

                  relative to the or each storage portion so as to limit a number of

-15   data transfer operations performed on the or each storage portion.

2. The method of claim 1, comprising adding a data transfer operation

   occurrence relative to a said storage portion to said record each time a

   data transfer operation is performed on said storage portion.

3. The method of claim 1 or 2, comprising limiting the number of data

20   transfer operations performed on the or each said storage portion to one,

   whereby no data transfer operation is performed on a previously used

   said storage portion.

4. The method of any of the preceding claims, wherein said storage unit

   comprises a tape storage medium and a non-volatile memory device, said

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5   method comprising storing on said non-volatile memory device at least

one of (i) the data transfer operation occurrence record and (ii)

information for identifying said storage unit as a designated reference

unit.

5. The method of any of the preceding claims, comprising monitoring error

10   levels in data transferred by the or each said transfer device and, in

response to detecting at one said data transfer device a said error level in

excess of a predetermined threshold, automatically inserting said

reference unit in said one data transfer device and performing a reference

data transfer operation.

15 6. The method of any of the preceding claims, comprising monitoring an

error level in data transferred during said reference data transfer

operation, and determining thereby whether a cause of the excessive error

level originates from said one data transfer device or from a said data

storage unit last removed from said data transfer device.

20 7. The method of any of the preceding claims, wherein a said data transfer

operation consists of a write operation followed by a read operation

performed on data written during said write operation.

8. The method of any of the preceding claims, wherein the recognizing step

is performed using at least one of (i) identity information stored on said

- 24 -

5   reference unit and (ii) detecting the presence of a said reference unit in a

specially designated holding location, and information obtained by

tracking subsequent movement of the reference unit.

9. The method of any of the preceding claims, wherein said reference unit is

a multi-function storage unit comprising i) a data storage tape comprising

10   said at least one storage portion and ii) a tape-cleaning band, the method

further comprising holding the multi-function storage unit in a dedicated

multi-function storage unit holding area, and moving said multi-function

storage unit to a data transfer device for use as a cleaning unit or as a

reference unit, as the case may be.

15   10.A program of machine readable instructions adapted to cause a digital

processor apparatus to perform the method of any of claims 1 to 9.

11.A carrier having stored thereon a program of machine readable

instructions adapted to cause a digital processor apparatus to perform the

method of any of claims 1 to 9.

20   12.A logic circuit of interconnected electrically conductive elements adapted

to perform the method of any of claims 1 to 9.

13.A control apparatus for use in at least one of an automated storage

apparatus or a data transfer device, said control apparatus comprising:

- 25 -

5 a) means for recognizing a digital data storage unit as a reference unit

for diagnostic use, said unit comprising at least one storage

portion;

b) means for using a record of data transfer operation occurrences

performed relative to the or each storage portion so as to limit a

10 number of data transfer operations performed on the or each

storage portion; and

c) means for adding a data transfer operation occurrence relative to a

said storage portion to said record each time a data transfer

operation is performed on said storage portion.

15 14. A digital data transfer device for transferring data to and from digital

data storage units, said device being adapted to:

a) recognize a said digital data storage unit as a reference unit for

diagnostic use, said reference unit comprising at least one storage

portion;

20 b) access a record of data transfer operations performed relative to the

or each said storage portion of said reference unit; and

c) use said record to limit a number of data transfer operations

performed on each said storage portion.

15. The digital data transfer device of claim 14, adapted to add to said record any occurrence of a data transfer operation by said transfer device relative to the or each said storage portion of said reference unit.

16. The digital data transfer device of claim 14 or 15, adapted to limit the number of data transfer operations to one per storage portion, whereby a virgin said storage portion is provided for any desired reference data transfer operation.

17. The digital data transfer device of any of claims 14 to 16, wherein said record is stored on said reference unit.

18. The digital data transfer device of any of claims 14 to 17, wherein said storage unit comprises a tape storage medium and a non-volatile memory device, and said record is stored on said non-volatile memory device.

19. The digital data transfer device of any of claims 14 to 18, adapted to monitor error levels in data transferred by said transfer unit relative to said data storage units and, in response to detecting a said error level in excess of a predetermined threshold, to:

    a) initiate i) removal of a said data storage unit presently inserted in said transfer unit and ii) insertion of a said reference unit; and

    b) perform a reference data transfer operation.

5 20. The digital data transfer device of any of claims 14 to 19, adapted to monitor an error level in data transferred during said reference data transfer operation, and determine thereby whether a cause of the excessive error level is located in said data transfer device or in the data storage unit last removed from said data transfer device.

10 21. The digital data transfer device of any of claims 14 to 20, adapted to recognize a said digital data storage unit as constituting a said designated reference unit for diagnostic use, by virtue of at least one of (i) identity information stored on said reference unit and (ii) information received from a controller of automated apparatus for moving, loading and

15 unloading storage units.

22. The digital data transfer device of any of claims 14 to 21, for use with a multi-function storage unit comprising i) a tape storage medium section having said at least one storage portion and ii) an abrasive cleaning tape section, said transfer device being adapted to recognize said multi-

20 function storage unit as a special type of reference unit, and to use an appropriate said section of said multi-function storage unit for cleaning purposes or for reference purposes, as required.

23. A digital data storage reference unit comprising i) at least one reference data storage portion and ii) a record of a number of times a data transfer

5   operation has been performed relative to the or each said storage portion,

so as to enable maintenance of the or each said data storage portion in a

predetermined reference condition.

24. The digital data storage reference unit of claim 23, comprising a cartridge

including a tape data storage medium and a fast access data storage

10   device, said record being stored on said fast access storage device.

25. The digital data storage reference unit of claim 23 or 24, comprising a

cartridge carrying an elongate multi-function band wound on at least one

reel, said band comprising;

   a) a first length constituting said at least one reference data storage

15   portion; and

   b) connected to and extending longitudinally away from said first

       length, a second length comprising abrasive cleaning medium.

26. The digital data storage reference unit of any of claims 23 to 25,

comprising identity information adapted to enable a digital data processor

20   to recognize said unit as a reference unit for diagnostic use.

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5

ABSTRACT

A method for use in an automated storage apparatus for moving digital data

storage units relative to at least one digital data transfer device, the method
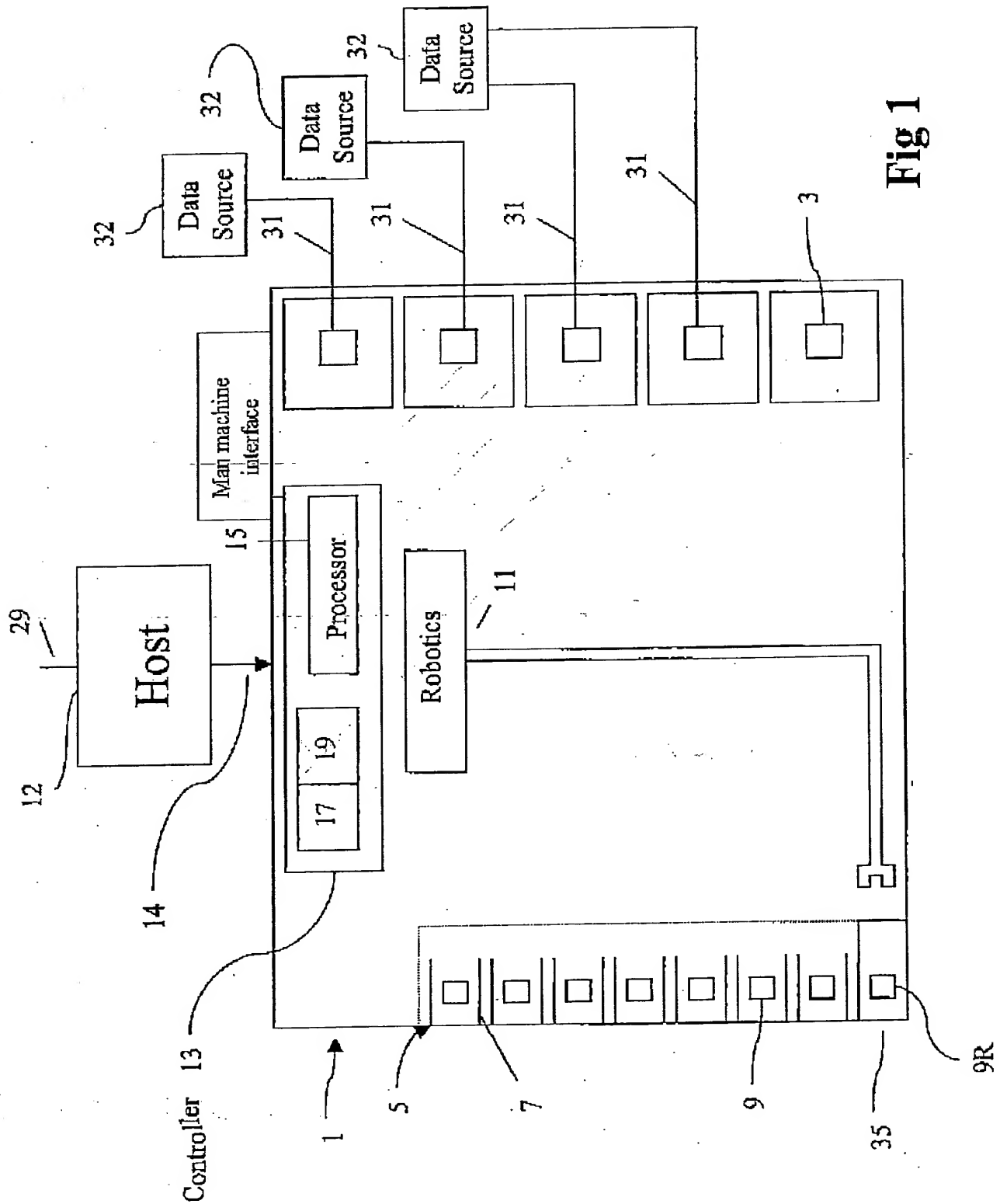
10   comprising:

   a) recognizing a designated one of said digital data storage units as a

      reference unit for diagnostic use, said unit comprising at least one

      storage portion; and

   b) using a record of data transfer operation occurrences performed

15   relative to the or each storage portion so as to limit a number of

      data transfer operations performed on the or each storage portion.

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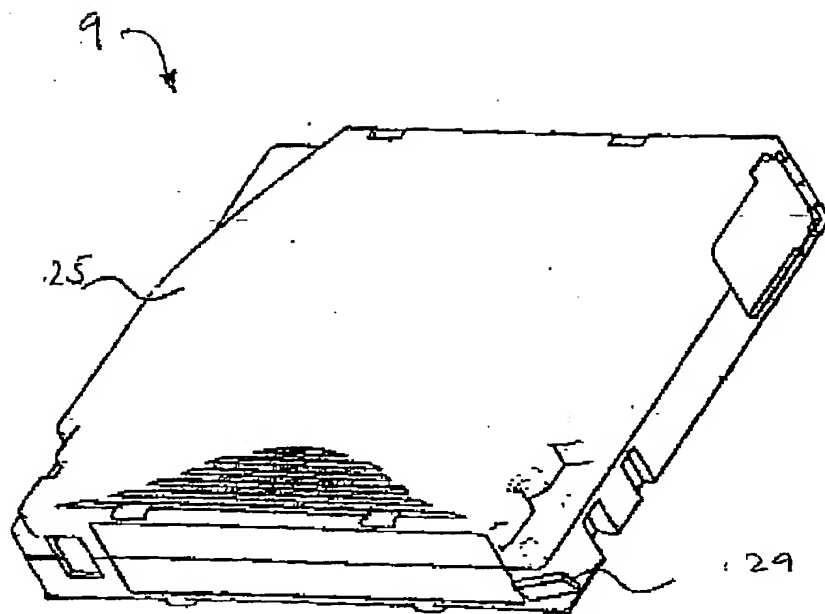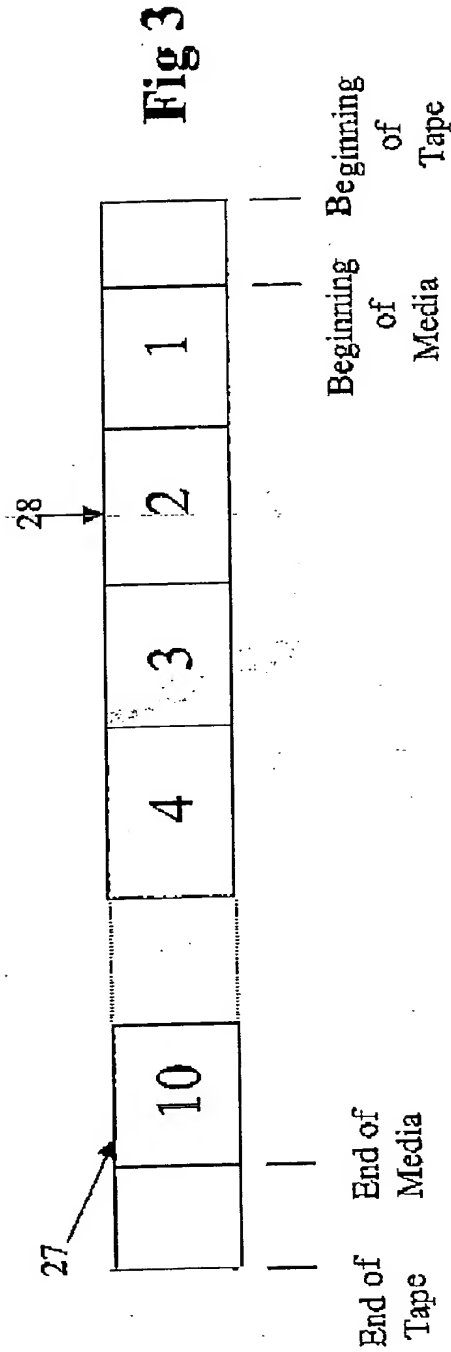
Fig 1

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Fig 2

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Fig 3

	1	2	3	4		10	

28 →

27 →

Beginning of Tape

Beginning of Media

End of Media

End of Tape

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Fig 4

Storage Portion	No of transfer ops
1	1
2	1
3	0
4	0
.	.
.	.
.	.
10	0

37

Fig 5

| 1 | 2 | 3 | 4 | | X | Abrasive Medium |

Beginning of Tape
Beginning of Media
28
End of Media
41
40
37
End of Tape

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Fig 6

61 — Storage unit signals high error rate

63 — Controller of automated apparatus receives signal

65 — Unload storage unit

67 — Load reference unit

69 — High error rate

YES — 71 — Drive fault: alert user and/or offline drive

NO — 73 — Media fault: alert user and/or make storage unit inaccessible
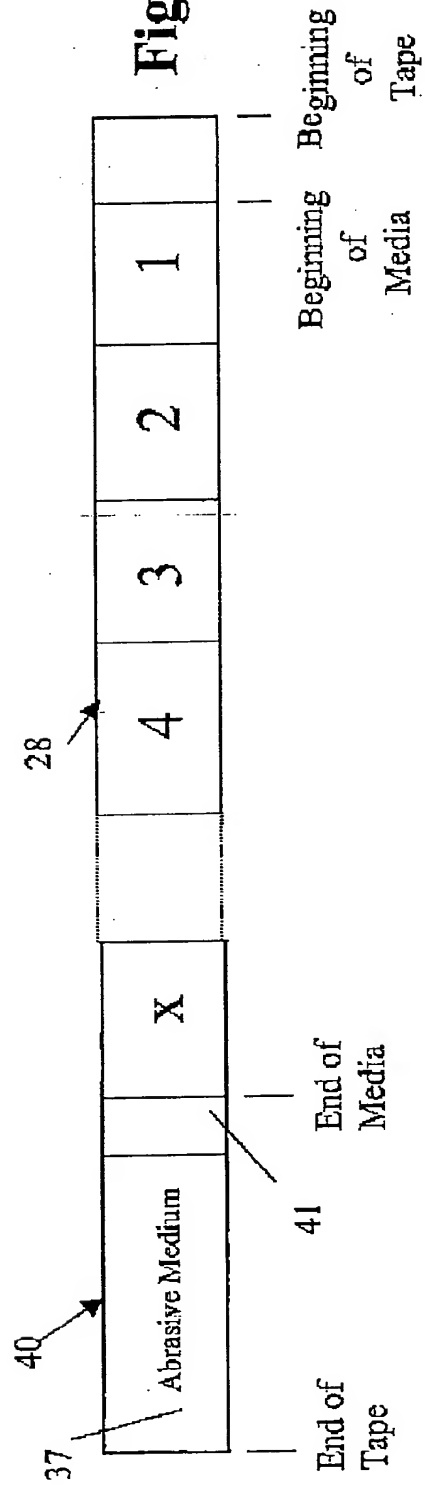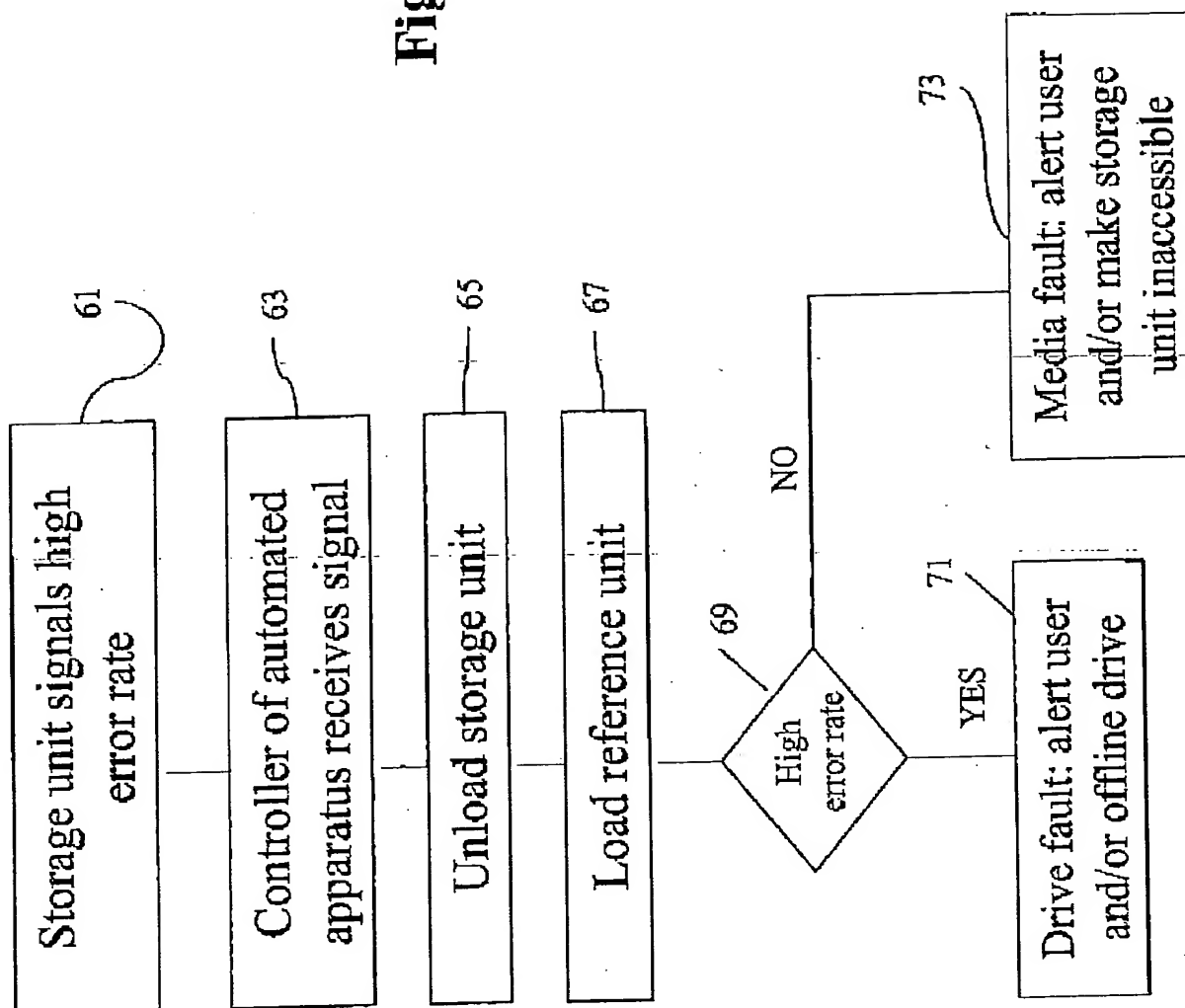
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Fig 7

```
┌──────────────────────┐
│  Recognize reference │  ── 81
│    storage unit      │
└──────────┬───────────┘
           │
┌──────────┴───────────┐
│  Access history of   │  ── 83
│  data transfers      │
│  to/from storage     │
│      portions        │
└──────────┬───────────┘
           │
┌──────────┴───────────┐
│  Perform data        │  ── 85
│  transfer to/from    │
│  unused storage      │
│      portion         │
└──────────┬───────────┘
           │
┌──────────┴───────────┐
│  Record occurrence   │  ── 87
│  of data transfer    │
│  to/from storage     │
│      portion         │
└──────────────────────┘
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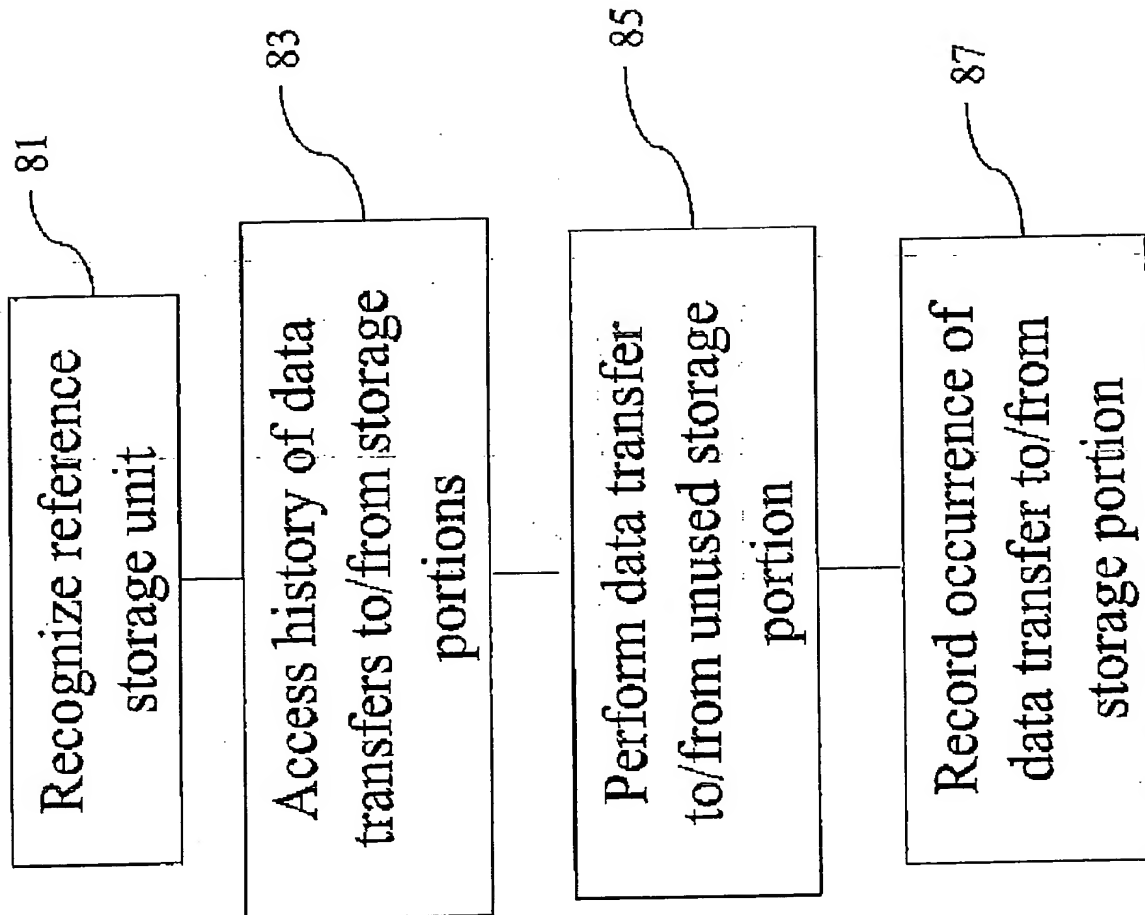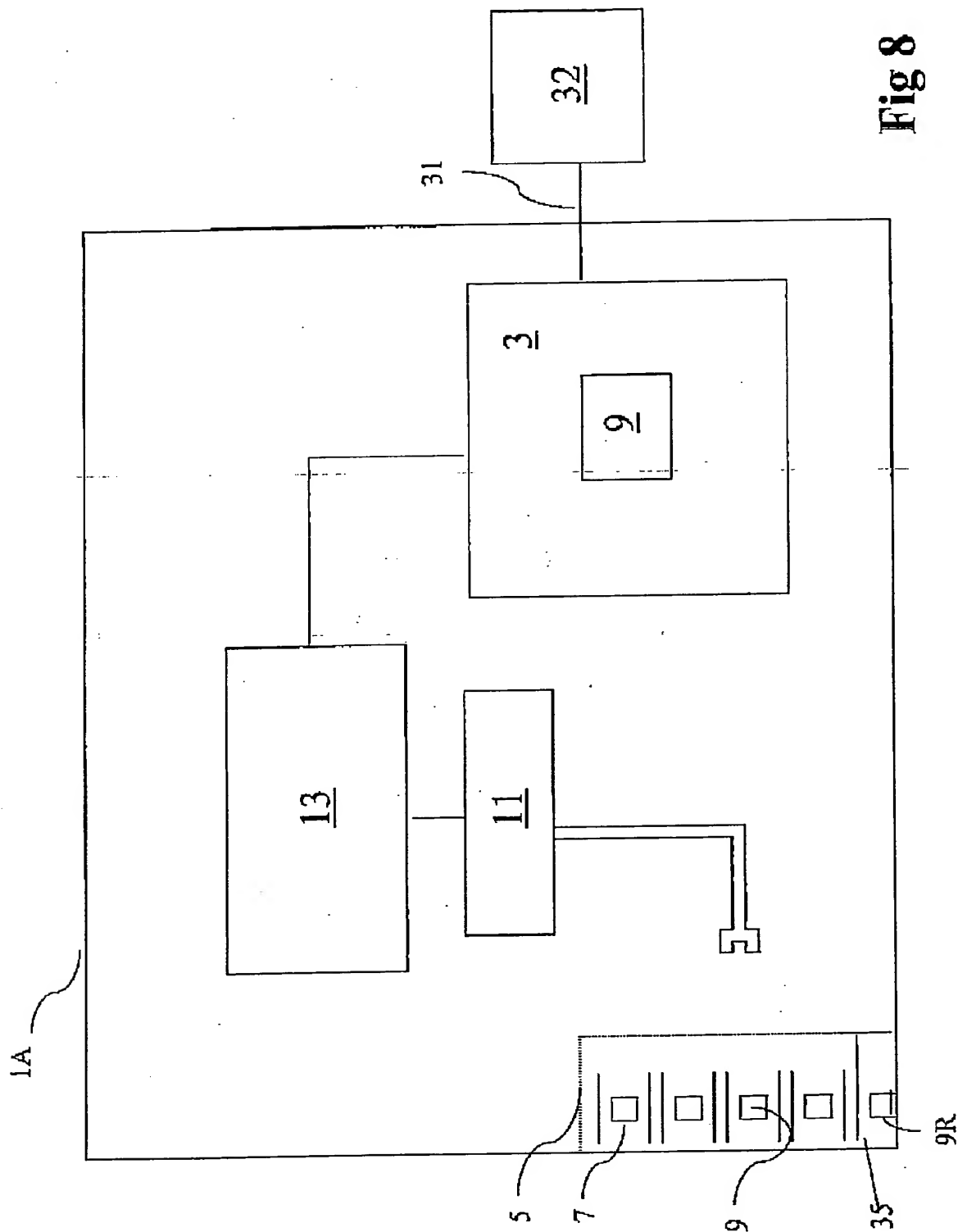
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Fig 8

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